Ecological Engineering 130 (2019) 228–232

Contents lists available at ScienceDirect

Ecological Engineering

journal homepage: www.elsevier.com/locate/ecoleng

Climate Change: Ecological and socio economic dimensions in the coastal zone

ARTICLE INFO

Keywords:
Climate change
Socio economic dimension
Coastal zone

ABSTRACT

This Editorial is the introductory text to the special section "Climate Change: Ecological and socio economic dimensions in the coastal zone" which is the result of the work developed to carry out the symposium of the same name held during the conference "EcoSummit 2016" in Montpellier, France, as well as the open call for papers published once the conference is over.

1. Introduction

This special section deals mainly with the consequences of climate-induced changes on several critical environmental drivers related to climate, which directly and indirectly regulate many coastal ecological processes. This is a critical concern for sustainable socio economic development in the twenty-first century (Day et al., 2014). According to the Fifth IPCC Assessment (AR5), coastal systems are particularly sensitive to three key drivers related to climate change: sea level, ocean temperature and ocean acidification. Coastal systems and low-lying areas will increasingly experience adverse impacts such as submergence, coastal flooding and coastal erosion due to relative sea level rise. Acidification and warming of coastal waters will continue with significant negative consequences for coastal ecosystems. The population, goods, services and assets exposed to coastal risks as well as human pressure on coastal ecosystems will increase significantly in the coming decades due to population growth, economic development, installation of energy generation infrastructure (coastal and marine), transportation networks and urbanization (Yañez-Arancibia, 2010, 2013, 2015).

Changing tropical storm activity, accelerated sea-level rise, increasing sea surface and atmospheric temperature, variability in the timing and quantity of precipitation and littoral erosion/accretion, among other phenomena, will be critical factors affecting the ecological integrity of coastal ecosystems as well as important societal activities (Day et al., 2013; Yañez-Arancibia, 2016). During the writing of this introductory text, hurricane "Irma" appeared and developed. This hurricane was considered the most powerful meteorological event to ever happen in the Atlantic Ocean in existing records (the category 5 storm had maximum sustained winds close to 300 km/h). Almost simultaneously, "Katia", "Irma" and "Jose" hit and left unprecedented damage in the Caribbean Sea and Gulf of Mexico region. With some days of difference another major hurricane, "Maria", hit several Caribbean Islands once more (September 16–30, 2017).

For the 21st century, the benefits of protecting against increased coastal flooding and land loss due to submergence and erosion at the global scale are larger than the social and economic costs of inaction. The relative costs of adaptation vary strongly between and within regions and countries for the 21st century. The analysis and implementation of coastal adaptation toward climate-resilient and sustainable coasts has progressed more significantly in developed countries than in developing countries (Wong et al., 2014). The use of combined approaches to coastal adaptation instead of a single strategy, such as the combination of ecology and engineering, allows for better preparation for a highly uncertain and dynamic coastal environment (Cheong et al., 2013).

The coastal zone is a dynamic place. It is a tridimensional conceptual limit in which hydrosphere and lithosphere meet and interact through very complex and often nonlinear mechanisms. Strong gradients and fluxes of matter and energy occur in coastal areas in latitudinal and longitudinal directions, where high-energy environments can be found near cozy, quiet places, producing a rich terrestrial and coastal biological diversity, high marine productivity levels, environmental goods and services, and beautiful landscapes, which in turn, attract human settlements and places to develop productive and strategic activities (touristic, commercial, industrial, fishery-related, extractive, security, protection, etc.). In the long-term, climate change will most likely alter the littoral zone, the species composition and biodiversity of coastal areas, and important ecosystem rates such as erosion, nutrient cycling and primary and secondary productivity (Walther et al., 2002; Day et al., 2013). Some elements of this system such as oceans, seas, rivers, estuaries, wetlands, costal aquifers, deltas, barrier islands, bays and beaches, have played and still play a key role in the evolution of human civilization and biological diversity. Since the ancient human migrations (Wells, 2002) or the initial intercontinental discovery journeys to the present "megahydropolis" development (Timmerman and White, 1997), global fishery practices or international cargo movement, the coastal zone has been a civilizing space.

https://doi.org/10.1016/j.ecoleng.2018.01.013
Received 12 December 2017; Received in revised form 3 January 2018; Accepted 31 January 2018
Available online 04 March 2018
0925-8574/

During the last decades, growing populations, natural vegetation cover loss and often chaotic or unplanned development along the world's coasts increase the vulnerability of littoral regions. Coastal regions are already confronting challenges that affect human systems (e.g. activities, institutions, settlements, transport infrastructure and networks) and coastal ecosystems such as shoreline erosion, coastal flooding, habitat degradation and water pollution will be exacerbated by the additional stress caused by climate change (EPA, 2016). Considering Integrated Coastal Area and River Basin Management (ICARM) principles, as well as the Ecosystem-based Approach (CBD, 2004; UNEP, 2006; Agardy et al., 2011), the coastal zone can be defined as the geographical region extended seaward up to the marine territorial limits and landward up to the watershed, including several ecosystems, coastal features, anthropogenic infrastructure and human activities that will be severely affected as a result of climate change impacts. Scientific research, technological innovations, education, social concern and global initiatives (e.g. blue economies, sustainable development goals) could alleviate the tremendous challenges that climate change could bring to coastal zones, but an extraordinary effort is needed to coordinate local, national and international actions and programs.

Coastal systems are particularly sensitive and respond to drivers of different rates, magnitudes, extensions and durations related to climate change (IPCC, 2007; Day et al., 2011; Pörtner et al., 2014; Wong et al., 2014). Coastal areas around the world are and will be the regions of the Earth that receive the most impact from the effects of climate change. According to Alejandro Yañez-Arancibia, "human-induced climate change needs to be the main concern of our society, not because of the change itself, but because of the risk it poses to our civilization as we know it".

2. The 5th International "EcoSummit 2016" in Montpellier, France

EcoSummit 2016, held in Montpellier France on August 29 through September 1, 2016, provided a forum for more than 1300 delegates from 75 countries to focus on finding solutions for today's massive environmental and ecological problems. Sessions were held on ecological engineering, ecological restoration, green infrastructure, adaptation to climate change, earth stewardship, ecohydrology, eco-informatics, ecological modeling, sustainable agriculture, protection of biodiversity, carbon sequestration, human ecology and enhancement of ecosystem services. The conference hosted 11 plenary presentations by some of the world's premier ecologists and environmental scientists; over 750 presentations were given in 93 scientific sessions; there were also 15 side events in the form of workshops, round tables and world cafes and more than 600 posters were displayed (Mitsch, 2016).

The symposium "Climate Change: Ecological and Socio Economic Dimensions in the Coastal Zone" was proposed by Alejandro Yañez and accepted by the organizing committee (scientific session 90). In the process of planning the event, Alejandro proposed the following thematic vision: "The coastal ecological integrity and socio economic impacts are at severe risk. This special session deals mainly with the consequences of climate-induced changes on several broadly critical environmental drivers related to climate, which directly and indirectly regulate many coastal ecological processes. This is a critical concern for future sustainable socio economic development in the twenty-first century. Some areas of coastal region in a broad latitudinal gradient will likely become wetter, some drier, and the variability in the timing and quantity of precipitation will also likely change. These patterns will reflect changes in local precipitation, freshwater runoff, and large drainage basins. Changing tropical storm activity, accelerated sea-level rise, and littoral erosion will be critical factors affecting ecological integrity of coastal ecosystems. Although the precise geography of these regional shifts in a broad latitudinal gradient is not known at present, it is expected that there will be significant changes in the fundamental character of many coastal ecosystems –from north to south- in response to a changing climate. Additionally, this special session will explore the concept of 'sentinel-ecosystems' and 'sentinel-species' in front of climate change impacts in the coastal zone".

The response of the international community was very important. More than 50 abstracts covering a broad spectrum of issues related with the socio economic dimensions of climate change in the coastal zone were received. After a peer review process, finally five oral presentations and several posters were included in the final program:

- Asmus and coworkers from Brazil. "The risk to lose ecosystem services due to climate change: A South American case"
- Equihua and coworkers from Mexico. "Ecosystem integrity assessment is key for a whole system approach to face climate change"
- Azuz and coworker from Mexico. "The impact of climate variability on agricultural and marine resources in Mexico's coastal zone"
- Nansen from India. "Environmental, ecological and socio economic issues associated with climate change and sea level rise on the coastal zones of India"
- Leauthaud and coworkers from France. "Characterizing floods in the poorly gauged wetlands of the Tana River Delta, Kenya, using a water balance model and satellite data"

The symposium was held in the Berlioz Hall, with Carles Ibañez (IRTA-Spain) as the chairperson invited by Alejandro Yañez, who could no longer travel to Montpellier. Around 40 to 50 people attended the presentations, even though it was the afternoon session of the last day of the summit.

The originality of this emerging subject is evident when we look at Fig. 1. A bibliographic search was done in Scopus search engine using the keywords "climate change" (CC), "climate change" and "coastal zone" (CZ) and finally "climate change" plus "coastal zone" and "socio economic". Over the last 25 years the number of scientific papers published has increased exponentially in the field of CC going from 1000 to 25,000 papers per year. The same exponential behavior could be observed with papers related to CC and CZ increasing from 30 to 1000 in the same period. In the case of the keywords CC + CZ + socio economic, only an average of 9–10 papers per year appear in the scientific literature, showing the research opportunities of this emerging line of work clearly identified by Alejandro Yañez.

3. This special section

This special section consists of seven research documents received in the open call for papers proposed following the thematic of EcoSummit 2016: "Climate change: Ecological and Socio Economic Dimensions in the Coastal Zone". The main topics of this special section will concentrate on: (1) ecosystem-based management applications; (2) mangrove-and-wetland-related issues; (3) renewable energy in islands and coastal zone; (4) risks associated with climate change.

Asmus et al. (2018) examined the effects of global climate change on oceans and coastal areas in terms of its impact on ecosystem services, developing a case study at the Patos Lagoon Estuary in Brazil. Based on information generated by scenarios predicted by the IPCC (RCP4.5 and RCP8.5) and from a significant database collected from interviews of several service users, the study involved the implementation of a model that

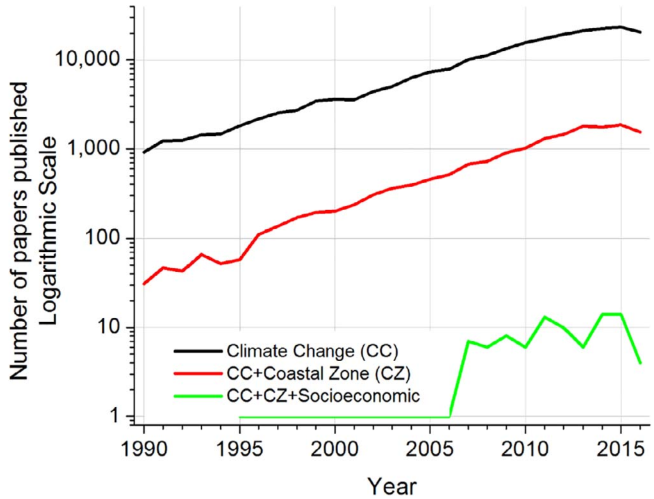

Fig. 1. Number of papers published in the field of "climate change", "climate change" plus "coastal zone" and, "climate change" plus "coastal zone" and "socio economic". Data form Scopus, December 2016.

estimates the risk of losing ecosystem services used by different stakeholder groups as a function of: (1) the climate threat; (2) the value of the service defined by the stakeholder's perception, and (3) the vulnerability of each group in relation to a possible service loss. Twenty ecosystems and/or environmental services were identified and three were selected for analysis (saltmarshes, agricultural systems and urban areas). The results demonstrate the relative importance of different ecosystems to generate essential services for the estuary, which can be taken as an important piece of information for planning and defining management policies.

Yanes et al. (2018) have proposed and analyzed the capabilities of a new methodology for conducting ecological risk assessment in coastal areas, focusing on ecosystem health. This approach eschews the conventional assessment model, which determines risk frequency by the number of past events and risk intensity by the magnitude of the phenomenon; threats are instead assessed from the human activities that amplify the effects of a given threat. Therefore, this constitutes an analysis of risk from the biocentric rather than the anthropocentric perspective, since it considers threats and vulnerabilities deriving from human disturbance as the main source of environmental problems. The methodology was applied in 16 ecosystems located in the Gulf of Urabá, in the coastal zone of Antioquia, Colombia (Caribbean Sea). Considering six analysis dimensions in the proposed model: a) coastal erosion, b) sedimentation, c) diapiric mud related to volcanic activity, d) invasive species, e) changes in land use and f) contamination related mainly with land-based activities – solid waste and sewage-, the authors assessed the frequency, intensity and territorial extension of the selected variables to assess the coastal risk. All the ecosystems analyzed present at least "high risk" in two of the dimensions studied. The proposed methodology – focused on ecosystem health – facilitates the identification of areas where strategic ecosystems are in risk and give information to support managerial actions related to ICZM.

Aguirre-Mendoza et al. (2018) address the potential use of renewable energy in small islands through a case study in Isla Grande in the Corales del Rosario archipelago, Colombia. Classified as a Natural National Park due to its marine and terrestrial biodiversity, Corales del Rosario was visualized as an optimal area for the assessment of the potential of use of wind energy and solar photovoltaic energy. In particular, Isla Grande – one of the largest islands in the archipelago – was chosen because large human settlements and touristic activities are present. Data from population, energy consumption, wind speed and direction, solar radiation and predominant ecosystem types, among other factors were collected. As an important result, the authors show that 58% of the Island population lacks electricity access and a total energy demand of 250 kWh/month was estimated for a typical Isla Grande house. After using several modeling and analytic tools to estimate the potential use of renewable energy, the paper discarded the use of wave, tidal or wind power. For one of the scenarios proposed in the document (type B = communal supply for the homes without electricity), the authors concluded that 570 photovoltaic solar panels of 240 W each could be enough to satisfy local energy demand.

Teutli-Hernandez et al. (2018) explored an important topic for the recovery of mangrove areas: the pioneering mangrove species. After the hydrological rehabilitation of Ria Celestum, a coastal lagoon located in the Yucatan peninsula in Mexico, the authors monitored the behavior (colonization and mangrove development) of two mangrove species for twenty months: *B. maritima and S. virginica*, as well as the sediment characteristics and time, frequency and level of flooding in the area of study. After a detailed analysis of the collected data, the author concluded that the results indicated that hydrological rehabilitation of heavily degraded mangrove areas (without cover of mangrove species) triggers a process of succession that starts with improving hydroperiod variables, followed by improving pore-water and sediment conditions, which favored succession wherein *B. maritima and S. virginica* were first established modifying the soil conditions for the arrival of mangrove seedlings. The coverage of these pioneering herbaceous species decreased with increasing height of mangrove individuals, probably due to overshadowing and competition for available sediment nutrients and space.

Vanegas et al. (2018) have conducted a field study to research the capacity of a natural *rhizophora* mangrove patch to mitigate incident wave energy in the coastal zone. The selected study area was located in Isla Grande in the Colombian Caribbean, and it covers an experimental area of 26.26 m^2. The geometrical characteristics of 97 mangrove roots were measured using manual techniques, and the hydrodynamics in the mangrove patch were measured with a 3 wave gauge array from May to November. To determine the percentage of wave height reduction when waves cross the vegetation, the energy dissipation was calculated based on the conservation of energy flux between several points and the linear sum of dissipation coefficients according to vegetation and bottom or breaking effects. One of the most important contributions of this paper was the field calculation of the drag coefficient (C_D), which once calculated could be incorporated into the dissipation equations for different sea states. Considering the experimental conditions presented in their study, Vanegas et al. (2018) obtained C_D values between 0.8 and 8.0 for Reynolds numbers of

3.0–7.35 × 10^5 and wave velocities ranging between 0.1 and 0.4 m/s. The study demonstrates the importance of mangrove preservation as a natural element that contributes to the dissipation of wave energy under regular and extreme conditions.

Osorio-Cano et al. (2018) presented a methodological framework and their assessment to quantify the impact of natural ecosystems in coastal protection using the effect of coral reef on flooding and coastal erosion under different – modeled – sea level rise and extreme meteorological events scenarios as a case study. After reviewing the different existing integrated models and tools to value ecosystem services in coastal habitats, the authors proposed a framework that incorporates the physical characteristics of the natural habitats, hydrodynamic and morphodynamic variables and the protective elements of the natural habitat in order to support adequate coastal management plans. A coral reef was selected as an example of coastal ecosystem to implement the proposed methodology, including a sensitivity analysis of the effect of coral reef degradation (changes in coral reef roughness) on wave height dissipation, wave run-up and coastal erosion. The authors concluded that their research might help solve the question of how effective a coral reef ecosystem could be in providing protection against coastal erosion and flooding, evidencing how hydrodynamic conditions may change in complex systems with high bottom roughness and providing insights for coastal managers and decision-makers to consider strategies in favor of natural habitat restoration and the use of coastal ecosystems in eco engineering solutions for coastal protection over traditional rigid or artificial infrastructure.

Lithgow et al. (2018) applied the ecosystem-based management approach to assess the effect of aquiculture on wetland degradation and water quality in a Wetland of international importance located in the North West Mexican Pacific (Marismas Nacionales). After analyzing the changes in mangrove extension and other vegetation classes, as well as increase or decrease in aquaculture ponds areas, the authors reported a 50% increase in aquaculture for 1997–2012. When sampling water quality and sediment sizes, Lithgow et al. (2018) found an increase in suspended solids, chemical oxygen demand (COD), phosphates, sulfates and chlorides between November 2013 and September 2014. A survey was conducted to assess the socio economic characteristics of the area and the perceptions about the spatial impacts of aquaculture on ecosystem services using expert groups and decision makers. The authors conclude that intensive shrimp farming is a major threat to the complex hydro-sedimentary dynamics of Marismas Nacionales. The analysis of sediment data showed that shrimp ponds negatively affect the parameters studied and the high load of suspended solids related with aquaculture effluents are enriched with nutrients, such as phosphates, and other pollutants, which can affect adjacent ecosystems.

Acknowledgements

We would like to thank William Mitsch and Jan Vymazal, Editors-in-Chief of the Journal of Ecological Engineering for their support and technical advice throughout the production of this Special Section, as well as the Center of Innovation and Design and the College of Engineering of CETYS University.

This Special Section is dedicated to Alejandro Yañez-Arancibia from Instituto de Ecología de Xalapa (INECOL), Mexico, who passed away unexpectedly on December 3, 2016.

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Isaac Azuz-Adeath[a,*], Alejandro Yañez-Arancibia[b,1]
[a] *Center for Higher and Technical Education (CETYS University), Km 1 Camino Microondas Trinidad S/N, Ensenada, Baja California, Mexico*
[b] *Instituto de Ecología A.C. (INECOL-CONACYT), Xalapa, Veracruz, Mexico*
E-mail address: Isaac.azuz@cetys.mx

[*] Corresponding author.
[1] This special section is dedicated to Alejandro Yañez-Arancibia, prominent Mexican/Chilean researcher who died on December 3rd, 2016 while actively working on the different dimensions of climate change and its impacts on the coastal zone.